Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

A 280.39
M 34Am
Cop. 3

AMS-470

TRANSIT TEMPERATURES in TRUCK SHIPMENTS of CALIFORNIA CITRUS FRUIT

U. S. DEPT. OF AGRICULTURE
LIBRARY
MAY 31 1962
CURRENT SERIAL RECORDS

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

ACKNOWLEDGMENTS

The cooperation and assistance of the following organizations are gratefully acknowledged:

Sunkist Growers, Inc., for furnishing fruit.

Field laboratory of Sunkist Growers, Inc., for assistance in loading.

Pacific Intermountain Express Co., for furnishing trucks and trailers for the tests.

Personnel of the Agricultural Marketing Service laboratory, Chicago, Ill., who inspected loads and recovered equipment.

CONTENTS

	Page
Summary and recommendations	3
Introduction	3
Preliminary tests	4
Main tests	6
Equipment	6
Thermograph locations	6
Chimney loads	6
Temperatures of lemons	9
Temperatures of oranges	9
Channel loads	9
Temperatures of lemons	12
Temperatures of oranges	12
Discussion	16

Washington, D.C. May 1962

TRANSIT TEMPERATURES IN TRUCK SHIPMENTS OF CALIFORNIA CITRUS FRUIT

By Ervin P. Atrops,[1] plant physiologist,
Market Quality Research Division
Agricultural Marketing Service

SUMMARY AND RECOMMENDATIONS

Substitution of the channel load for the customary solid load or chimney load in refrigerated trucks and installation of baffles between the top of the load and the truck ceiling greatly improved the cooling rate and lowered the average transit temperature of citrus fruit. These improvements should result in longer distribution life of fruit at the markets and improved quality of fruit for the consumer.

The temperatures in 29 truckloads of citrus fruit from the loading point in southern California to midwestern markets were obtained by thermographs to study the effect of loading patterns on cooling rates. Twenty-eight of these loads were refrigerated mechanically, and one preliminary test load was cooled by water ice. Initially the chimney load was used and later the channel load.

Average temperatures of lemons in chimney loads remained about the same as at loading when the thermostat was set near 45° F. Warm oranges in middle layers of chimney loads cooled only slightly while in transit when the thermostat was set at 35°. The small amount of carton surface exposed to the airstream in this kind of load does not permit good heat removal.

Channel loads permit more rapid removal of heat from loads of warm oranges than chimney loads. In five tests the average temperature of the load was reduced 14 degrees F. or more in the first 48 hours after loading. Factors other than load pattern that adversely affect cooling rate are improperly calibrated thermostats, low air-volume fans, and inefficient operation of refrigeration units.

Cooled air should be circulated at a rate of at least 1,000 cubic feet per minute, and probably 2,000 cubic feet per minute would be nearer the ideal. Thermostats should be calibrated frequently to make certain that the cutoff temperature is near the thermostat setting.

A canvas or plastic baffle should be used to force the cooled air through the load and prevent it from returning directly to the evaporator from the supply duct.

A space of about 6 inches must be kept open between the rear door and the load. With some equipment a gate may be necessary to hold the load.

INTRODUCTION

The use of trucks has become increasingly important in the transport of citrus fruit from California to destinations in the central and northern States. At the request of California shippers, studies were conducted to determine the prevailing temperatures of the fruit as it moved by truck to points as far east as Chicago, Minneapolis, and Kansas City, and if necessary, how to improve these temperatures. These studies are part of a broad program of marketing research designed to maintain the quality and reduce the spoilage of farm products during marketing.

[1] Author is stationed at Pomona, Calif.

PRELIMINARY TESTS

In July 1956, thermographs were placed in the first of three preliminary truck shipments (test A). This was a chimney load of lemons in nonvented cartons loaded at Santa Barbara, Calif., for delivery in Chicago, Ill. The five thermographs were located in the middle layer of forward stack,[2] middle layer halfway to the rear, and top, middle, and bottom layers at the rear door. The thermostat of this mechanically refrigerated van was set at 45° F. The loading temperature of the fruit was 61°. On arrival at Chicago 6 days later, the average fruit temperature was 65° (table 1). After 4 days' holding in the truck at destination, the average temperature had only been lowered to 60°, and the range was from 57° to 70°.

On August 23, 1956, a second trailer (test B) was loaded at Redlands, Calif., in a solid load pattern with 910 cartons of warm oranges. This trailer was equipped with a bunker for water ice and a circulating fan powered by a small gasoline engine. An air duct brought the cooled air halfway to the rear of the trailer. Thermographs were placed in cartons in the top, middle, and bottom layers at the bunker, halfway to the rear, and at the rear of the load. One additional thermograph recorded the temperature of return air at the bunker; this temperature averaged 57° F. for the trip. Average loading temperature of the fruit was 87°. When fruit was unloaded at Minneapolis 4 days later, fruit temperatures as recorded by the nine thermographs averaged 62°, a reduction of 25 degrees (table 2). This reduction in temperature came from cooling at the bunker and at the rear of the load only. Temperatures in the top and middle layers at the halfway position remained in the high 80's; the temperature in the bottom layer at the halfway position was 70° at unloading. Ice meltage totaled 5,750 pounds for the trip. Fruit temperatures in the nine locations averaged 71° for the trip.

The third preliminary truck shipment (test C) consisted of oranges shipped from Piru, Calif., to Des Moines, Iowa, in September 1956. Nine thermographs recorded fruit temperatures in this load. They were located in the second and fifth layers of the forward stack, the forward quarter-length, rear quarter-length, and in the first, fourth, and seventh layers at the rear door. Return air temperatures were recorded by a thermograph at the refrigeration unit. The thermostat in this mechanically refrigerated trailer was set at 40° F. The load was planned to have lengthwise channels from front to rear in the second, fourth, and sixth layers. The cartons were loaded crosswise, five cartons forming a solid layer and four cartons a channel layer (5, 4, 5, 4, 5, 4, 5). The first digit represents the number of cartons in the bottom layer of a stack and succeeding numbers show the other layers in order. Loading was made difficult by having to load through the side door, and in all probability some of the channels were closed at about midpoint of the load. This unit had no air ducts leading from the evaporator, and no air baffles were installed.

Average loading temperature was 77° F., and 3 days later at Des Moines the average fruit temperature, as recorded by the nine thermographs in cartons of fruit, was about 62° (table 2). The top layer averaged 52°, middle layer 72°, and bottom layer 74°. The average fruit temperature for the trip was 69°. The return air at the refrigeration unit averaged 52° for the trip. This is the same average temperature as recorded in a carton at the top rear of the load. The driver indicated on his report that the refrigeration unit was cycling off and on at 40° only 24 hours after loading. With some temperatures in middle and bottom layers still in the 70's at destination it is apparent that refrigerated air was not reaching these positions, but was short circuiting over the top of the load where resistance to airflow was lowest.

---

[2] In this report, a "stack" is a row of cartons from one sidewall of the trailer to the other sidewall. "Middle" refers to vertical location with reference to layers.

Table 1.--Average temperatures in nonvented cartons of lemons shipped by truck from southern California to Chicago, and description of loads and equipment used[1]

Test number and date shipped	Temperature: At loading	Temperature: After 48 hours	Temperature: On arrival	Thermostat setting	Cutoff temperature	Air delivery	Type of load: No. of cartons per layer[3]	Type of load: Loading pattern[4]	Number of cartons	False bulkhead for return air	Air baffle	Floor racks
	°F.	°F.	°F.	°F.	°F.	C.f.m.						
1956												
A[2] July 24	61.0	62.0	65.0	45	---	---		Bcy	825	None	None	None
1957												
2 Feb. 15	60.0	60.4	60.4	50	54	---		Bcy	828	None	None	Yes
4[5] Feb. 21	60.6	57.0	56.6	50	54	420		Bcy	825	5" duct	Forward	Yes
6 Mar. 8	60.0	59.0	58.8	46	48	800		Bcy	825	6" duct	Forward	Yes
8 Mar. 15	58.2	49.8	47.8	46	44	1,400	7666677	Ocl	828	None	Central	None
10[5] Mar. 22	58.4	55.4	52.0	46	51	420		Rcy	825	5" duct	Central	None
12 Mar. 29	64.2	57.4	53.2	46	50	1,000	7667667	Ocl	828	None	Central	Yes
14[6] Apr. 5	58.2	49.0	48.2	46	46	950	7667667	Ocl	828	None	Central	Yes
16 Apr. 12	55.6	52.0	51.2	46	48	800	7667677	Rcl	826	None	Central	Yes
18[6] Apr. 19	60.0	52.4	52.0	46	47	950	7667677	Rcl	822	None	Central	Yes
20 Apr. 26	55.0	52.0	47.2	46	40	1,000	7667677	Rcl	822	None	Central	None
22 May 3	59.2	53.6	46.6	46	48	1,200	7667677	Rcl	822	None	Central	Yes
24 May 10	59.2	57.2	59.4	46	53	1,100	7667677	Rcl	822	None	Central	Yes
26 May 18	59.4	55.6	55.8	46	50	1,000	7676767	Alt.	822	None	Central	Yes

[1] Average temperature obtained from 5 thermographs.
[2] Preliminary test.
[3] Digits indicate number of cartons in each layer of a seven-layer stack, beginning with bottom layer.
[4] Bcy = bonded chimney; Rcy = registered chimney; Ocl = offset channels; Rcl = registered channels; Alt. = alternate layers channeled.
[5] The same trailers were used on tests 4 and 10.
[6] The same trailers were used on tests 14 and 18.

Table 2.--Average temperatures in vented cartons of oranges shipped by truck from southern California to Chicago, and description of loads and equipment used[1]

Test number and date shipped	Temperature: At loading	Temperature: After 48 hours	Temperature: On arrival	Thermostat setting	Cutoff temperature	Air delivery	Type of load: No. of cartons per layer[3]	Type of load: Loading pattern[4]	Number of cartons	False bulkhead for return air	Air baffle	Floor racks
	°F.	°F.	°F.	°F.	°F.	C.f.m.						
1956												
B[2] Aug. 23	87.2	69.7	62.3	None	---	---	Solid		910	4" duct	None	None
C[2] Sept. 11	77.4	66.7	61.6	40	54	---	5454545	Alt.	900	None	None	Yes
1957												
1 Feb. 13	74.4	67.0	63.0	40	45	---		Rcy	825	None	None	Yes
3 Feb. 20	64.0	55.8	52.0	38	36	600		Rcy	825	3" duct	Forward	Yes
5 Mar. 6	69.0	60.6	55.0	35	46	500		Rcy	825	6 1/2" duct	Forward	Yes
7 Mar. 13	64.6	57.8	53.6	35	43	---		Rcy	825	5 1/2" duct	Forward	Yes
9 Mar. 20	67.6	55.2	57.2	35	42	500		Rcy	825	None	Central	Yes
11 Mar. 27	69.6	59.8	51.6	35	49	1,100	7667667	Ocl	828	None	Central	Yes
13 Apr. 3	71.4	58.0	44.4	35	32	1,200	7667667	Ocl	828	None	Central	None
15 Apr. 10	69.0	58.2	53.4	35	43	800	7667677	Ocl	818	None	Central	Yes
17 Apr. 17	69.4	52.2	47.8	35	28	1,200	7667677	Rcl	826	None	Central	Yes
19 Apr. 24	62.6	57.6	54.0	35	49	1,400	7667677	Rcl	822	None	Central	None
21 May 1	71.2	63.8	47.8	35	45	1,000	7667677	Rcl	822	None	Central	Yes
23 May 8	71.4	52.2	49.2	35	40	2,400	7667677	Rcl	822	None	Central	Yes
25 May 15	72.0	50.0	45.6	35	42	1,400	7676767	Alt.	822	None	Central	Yes

[1] Average temperature obtained from 9 thermographs in tests B and C; from 5 thermographs in numbered tests.
[2] Preliminary tests.
[3] Digits indicate number of cartons in each layer of a seven-layer stack beginning with bottom layer. In test C, the cartons were loaded crosswise of the trailer.
[4] Alt. = alternate layers channeled; Rcy = registered chimney; Ocl = offset channel; Rcl = registered channel.

MAIN TESTS

The results obtained from the preliminary tests showed that desired transit temperatures were not being attained with the loading patterns being used. Accordingly, in February 1957 a series of 26 truck shipments was initiated. These were loaded at southern California packinghouses and shipped to Chicago, Ill. Odd-numbered tests were made with oranges and even-numbered tests with lemons. Test loads 1 and 3 were from Piru, Calif. The remaining oranges, tests 5 through 25, were from Riverside, Calif.

Lemons for tests 2 and 4 were loaded at Saticoy, Calif., and the remaining lemons, tests 6 through 26, at Upland, Calif.

Equipment

The 35-foot trailers were equipped with refrigeration units mounted on the front end of the trailers. The trailers had about 4 inches of spun glass insulation and inside paneling of either corrugated plastic or plywood with 1-inch slanted strips to keep cartons away from the sidewalls. Extruded aluminum floor strips formed 1 1/8-inch to 1 3/4-inch rectangular ducts for air passages under the load. Removable floor racks made of 1- by 4-inch lumber nailed on 2- by 2-inch stringers, which ran lengthwise of the trailer, were used in most tests.

The trailer body was supported on the running gear by pneumatic cushions. This is one of the easiest riding forms of suspension; it is therefore possible that some of the channel load patterns used in these tests with entirely satisfactory results may not prove satisfactory with other types of suspension. There was no opportunity to observe the performance of these channel load patterns in trailers with other types of suspension, but some independent owner-drivers said they had had satisfactory results with alternate channel layers on spring or torsion bar suspensions on long hauls.

Thermograph Locations

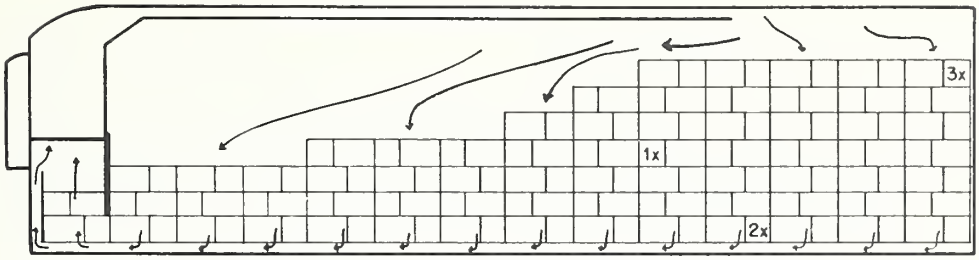
A minimum of three thermographs was used to record fruit temperatures in each test. These were placed in cartons of fruit on the centerline, in the fourth layer near the halfway position, in the first or second layer at rear quarter-length, and in the top layer (seventh) at the rear in a carton exposed to the airstream from the refrigeration unit (figs. 1 and 2). This top rear position most nearly represented the temperature of the cooled air.

Chimney loads

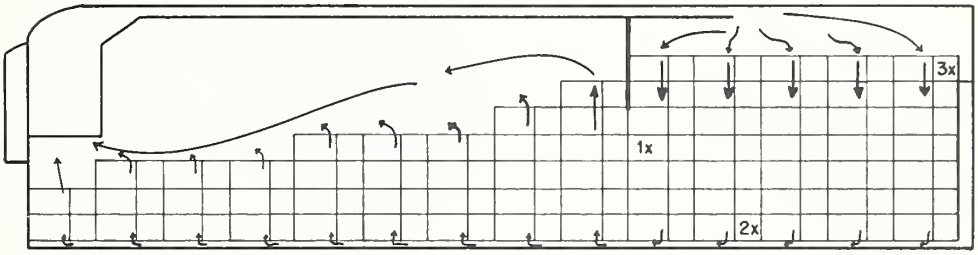
The chimney pattern was used for tests 1 through 10 (except number 8). This is a stable load, especially when the stacks of cartons are bonded. It carries well in refrigerated rail cars, but did not adapt well to all trailers because the three-wide chimney load was too wide for many trailers.

Thermostats for loads of lemons were set at 46° F., except tests 2 and 4 in which they were set at 50°. Thermostats for loads of oranges were generally set at 35°; exceptions were test 1, in which the thermostat was set at 40°, and test 3, at 38°.

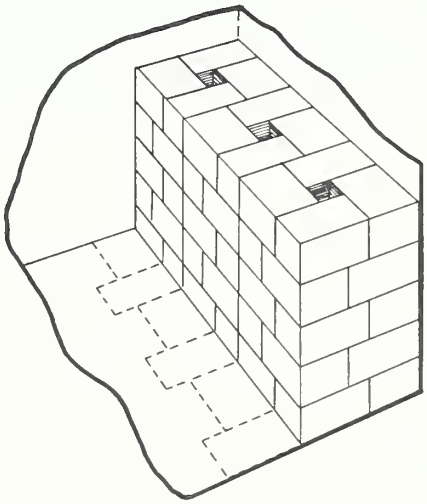
Air velocity from the delivery duct was measured by anemometers in six trailers with chimney loads and the volume calculated therefrom. The range was from 420 to 800 cubic feet per minute and averaged 540 c.f.m. This was too low for effective cooling. One reason for the low airflow may have been the partial closure of chimneys by the floor racks. All chimney loads except 2 and 10 were on removable floor racks. Floor racks were blocked at the rear with corrugated fiberboard on chimney loads to force all available air through the chimneys.



A

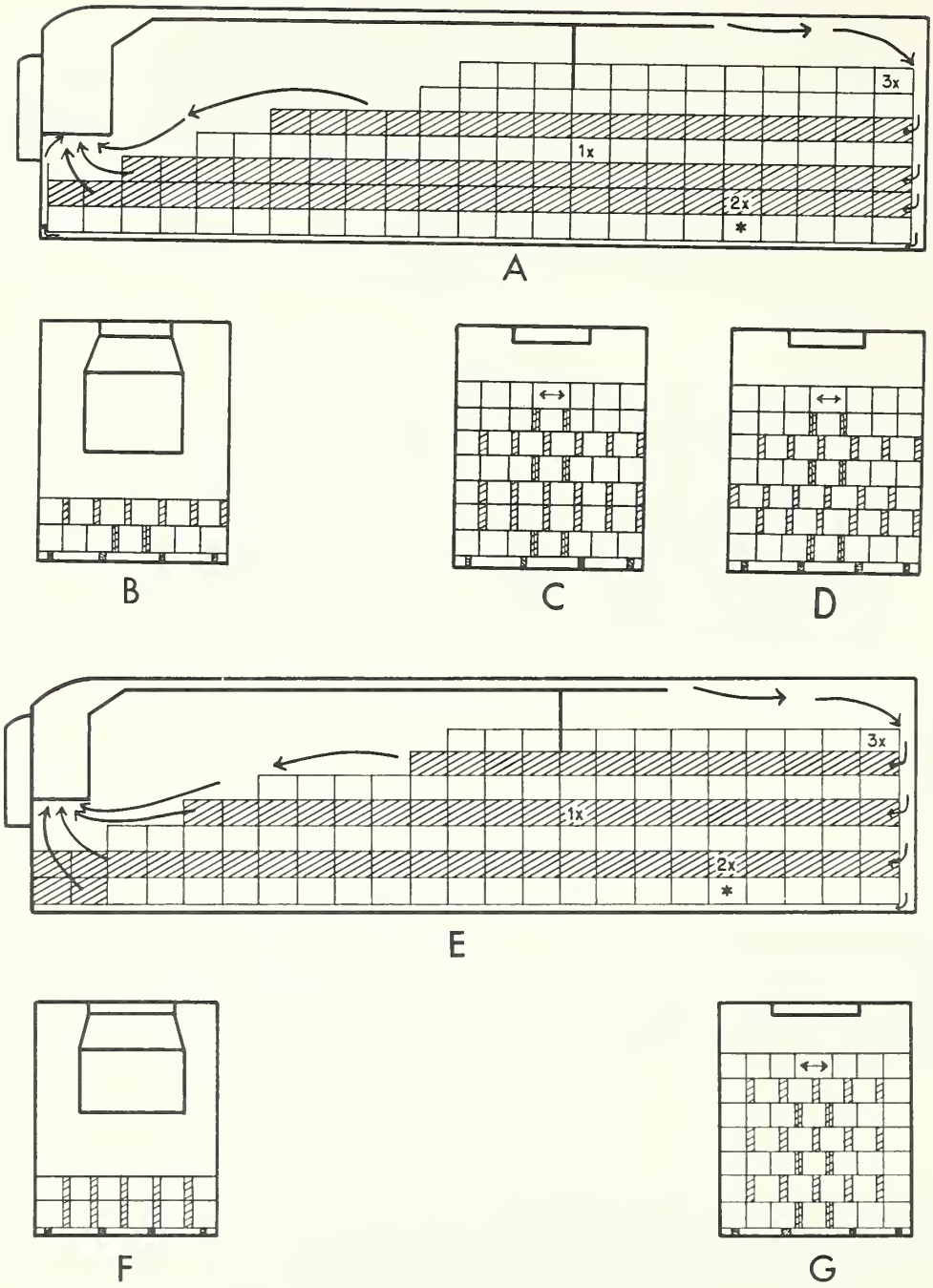


B



C

Figure 1.--(A) Arrows indicate airflow when forward baffle, false bulkhead, and bonded chimney load are used. No space is left between rear door and rear of load. (B) Airflow when a centrally located air baffle is used (tests 9 and 10). Space between rear door and rear of load is blocked to force all the air through the chimneys. (C) The chimney load pattern as adapted to truck trailers. (Note small area of carton surfaces exposed to the cooling air.)



*IN TESTS 8 & 13 THE REAR QUARTERLENGTH THERMOGRAPH WAS PLACED IN THE BOTTOM LAYER.

Figure 2.--(A) A lengthwise channel load of the type 7, 6, 6, 7, 6, 7, 7 (7 cartons in bottom layer of crosswise stack, 6 cartons in 2d and 3d layers, and so forth) with a centrally located baffle. (B) Channel spacing of the 2 forward stacks is the same as in the bottom layers of the remainder of the load. (C) Registered channels in second and third layers (cartons in two layers are alined so that channels in upper layer are directly above channels in layer below). Center carton of top layer is loaded crosswise for increased stability. (D) Offset channels in 2d and 3d layers. In test 8 this pattern was repeated in layers 4 and 5. (E) Alternate layers channeled (type 7, 6, 7, 6, 7, 6, 7) with the baffle located centrally above the load. (F) Registered channels in forward stacks eliminate the need for a false bulkhead. Pressure-sensitive tape should be used to maintain spacing. (G) Rear stacks of load when alternate layers are channeled. Center carton of top layer is loaded crosswise for increased stability.

Air baffles were built into the forward part of loads 3, 4, 5, 6, and 7; and above the load, about midway between front and rear, in tests 9 and 10 (fig. 1A). These baffles were intended to force more of the air through the load and prevent short circuiting. The central baffle (at the halfway point above the load) proved most satisfactory and was used on all the subsequent channel loads (fig. 2A, E). Trailers used in these later tests had air ducts extending about three-fourths the length of the trailer. Duct openings forward of the baffle were blocked.

On chimney loads 3, 4, 5, 6, 7, and 10, a false bulkhead was built ahead of the load. This formed a vertical passage through which the warm return air from under the load could return to the evaporator (fig. 1A). The depth of this bulkhead was varied with the individual trailer to enable 14 chimney stacks of cartons to be loaded. The forward chimneys of test 9 served as the return air ducts (fig. 1B). The false bulkhead used in test 10 which, like 9, had a central baffle above the load, served no real purpose except to shift the entire load about 5 inches to the rear.

None of the attempts to improve cooling in middle layers of chimney loads was successful. After nine tests, four with lemons and five with oranges, this pattern was abandoned in favor of the channel load, which exposed much more carton surface to circulating air and permitted more air to circulate through the load.

Temperatures of lemons.--Lemons were packed in nonvented cartons. Fruit temperatures recorded by thermographs in the middle layer at the halfway position of chimney loads usually remained about the same as at loading, but in some tests they increased 3 to 9 degrees F. during transit. Lemon temperatures for chimney loads (tests 2, 4, 6, and 10) are shown in figure 3. The poor cooling was probably due to the low air movement in these trucks, the highest measured being 800 c.f.m. in test 6.

Temperatures of oranges.--Thermograph records showed that middle layers of warm oranges cooled only slightly with the chimney load even though they were packed in ventilated cartons. Average cooling of middle layers during transit was about 5 degrees F. (range 3 to 10 degrees). The top rear and the bottom rear quarter-length positions cooled 10 to 15 degrees more during a trip than the middle halfway position (fig. 4).

Channel Loads

Because poor temperatures were obtained with the chimney load pattern, channel-type loads were used in test 8 and tests 11 through 26. Channels were formed by placing six cartons lengthwise of the trailer in each stack for a channel layer. With outside rows against the corrugated sidewalls and cartons spaced evenly, five channels, each about 3 inches wide and 10 inches high, were formed per layer throughout the length of the load. In these tests, the channel layers were placed in various positions between layers that were seven cartons wide (fig. 2 C and D).

The loads in these tests ranged from 822 to 828 cartons. Forward stacks under the evaporator were never loaded more than three layers high, many only two layers. As loading progressed toward the rear, stacks were stepped up one layer at a time until the load was seven layers high after the 10th or 11th stack. The height to which forward stacks were loaded depended upon the weight the truck drivers specified; 10,000 pounds in the front half of the trailer was satisfactory for normal road conditions. When wet or icy road conditions were expected, the drivers asked for additional weight over the tractor drive wheels to improve handling and control of the trailer. These trailers held 23 lengthwise stacks of cartons with about 6 inches remaining between the rear of the load and the door. This space formed a vertical duct by which the chilled air from the evaporator entered the lengthwise channels.

The stacks in the front end were always arranged so the air coming through the lengthwise channels of the load could return to the evaporator without a great deal of resistance. When these stacks were only two or three layers high, this was easily

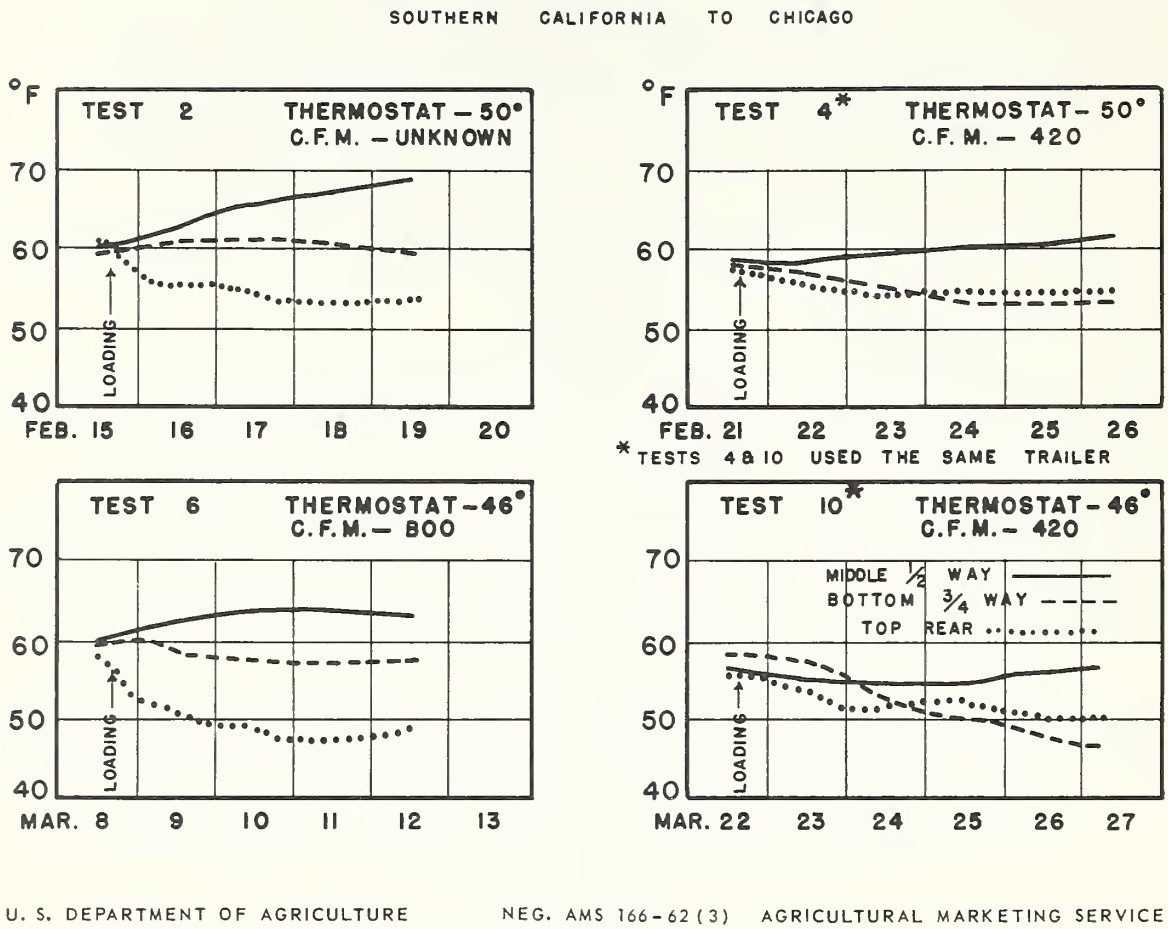
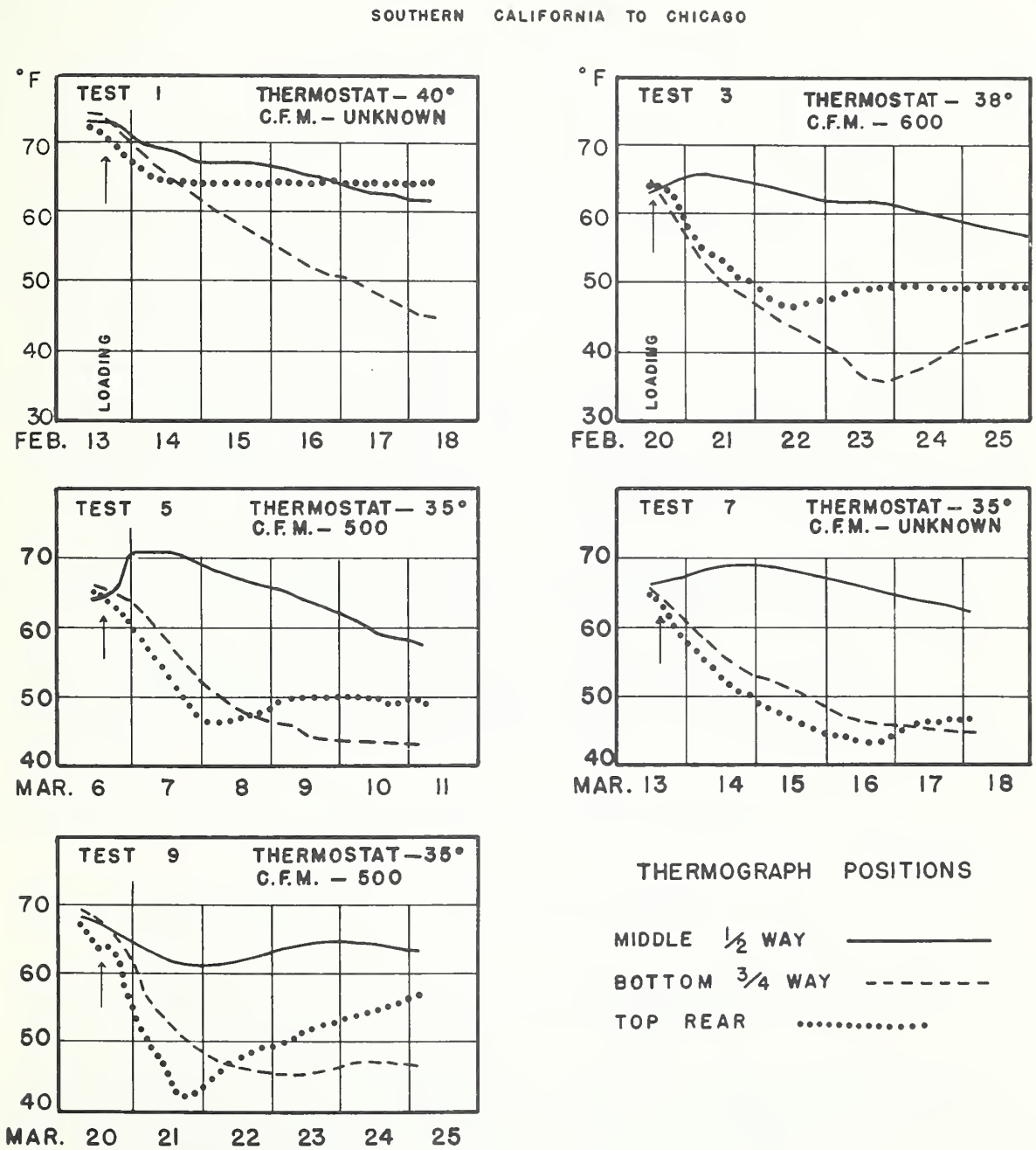


Figure 3

accomplished by nailing 1- by 2-inch strips vertically to the front bulkhead to maintain the spacing of the cartons in the first stack. In this way unbroken channels were formed through the bottom layers for the entire length of the load (fig. 2 A, B, C, and D).

A second method of providing low resistance for the air return at the front end was by spaced stacks in which the cartons were registered (one directly above the other) (fig. 2 F). This method offers less resistance to airflow than the strips, because of the greater area available. The spacing of these cartons, however, must be maintained throughout the trip. In these tests pressure-sensitive filament tape was used to secure the cartons. In the forward stacks, which were three layers high, one strip of tape was used crosswise of the trailer on top of the second and the third layers. Slippage toward the front was no problem as long as cartons were stepped up only one layer at a time. Spaced cartons in top layers were secured with a strip of tape to maintain channels.

The load pattern of test 8 (lemons) was of the type 7, 6, 6, 6, 6, 7, 7. The first digit represents the number of cartons per stack in the bottom layer, and succeeding numbers represent the other layers in order. All cartons in the six lower layers were loaded lengthwise. Each of the four spaced layers of test 8 were offset from the layer above and below to form channels 10 inches high. Although this load carried without shifting and cooled well, it was very difficult to maintain spacing of cartons for channels while loading.



U. S. DEPARTMENT OF AGRICULTURE NEG. AMS 167-62 (3) AGRICULTURAL MARKETING SERVICE

Figure 4

Tests 11, 12, and 13 were of the type 7, 6, 6, 7, 6, 6, 7 with the spaced layers offset.

Tests 14 and 15 were of the type 7, 6, 6, 7, 6, 7, 7 with the second and third layers offset (fig. 2 D). Tests 16 through 24 were of the same type except that second and third

layers were registered (cartons in vertical alignment), to form channels about 20 inches high (fig. 2 C).

The pattern finally selected for ease of loading and satisfactory cooling was the alternate channel load, as shown in figure 2 E and G. It was designated 7, 6, 7, 6, 7, 6, 7 for a seven-layer load and was used in tests 25 and 26. A method of loading the forward stacks to provide channels for the return air is shown in figure 2 F. The outside cartons were placed against the sidewalls, to which wooden strips or corrugated plastic were attached. The strips or corrugations provided for air movement around the load to remove heat leakage from the outside. A total of 21 lengthwise channels were made through the central portion of the load. The surplus space in the three lower layers that were seven cartons wide was utilized to form lengthwise channels on each side of the center carton. The top (seventh) layer was loaded solid, that is, six cartons lengthwise and one carton crosswise. This solid layer increased the stability of the load and forced more of the air to enter the lengthwise channels at the rear. Air velocity through these channels ranged from 120 to 200 feet per minute. A fiberboard baffle was placed across the center of the load between the evaporator and the discharge openings of the cold air ducts to prevent the air from taking a shortcut over the top of the load to the evaporator (fig. 2 E).

Temperatures of lemons.--Temperature records for the nine (even-numbered) tests with lemons in channel loads are shown in figure 5. The thermostats were set at 46° F. Average loading temperatures ranged from 55° to 60°, except number 12 which was 64.5°. Average temperature reductions 48 hours after loading, as recorded by five thermographs in each test, ranged from 2.0 to 9.2 degrees, in contrast to a rise of 3.0 to 9.0 degrees in chimney loads of lemons.

The range of cooling in channel loads was primarily the result of differences in the operational efficiency of thermostats, fans, and refrigeration units rather than in load patterns for the reasons explained in the following paragraphs.

The approximate temperature of the air from the evaporator coils was recorded by the top rear thermograph. The lowest temperature of the air recorded at this position indicates the cutoff temperature of the thermostat as given in table 1. With a thermostat setting of 46°, the cutoff temperature ranged from 40° F. in test 20 at destination to 53° in test 24 only 60 hours after loading.

The fans in different trailers with channel loads of lemons furnished volumes of air varying from 800 c.f.m. in test 16 to 1,400 c.f.m. in test 8. The average for the 9 tests was 1,040 c.f.m.

The slow temperature reduction of the delivery air from the evaporator coils in tests 20 and 22 indicates refrigeration units which were not operating efficiently.

In general the lemon temperatures in the channel loads were satisfactory. Test 24 was less satisfactory than the others because an improperly calibrated thermostat caused the temperature at the middle halfway position to rise (fig. 5).

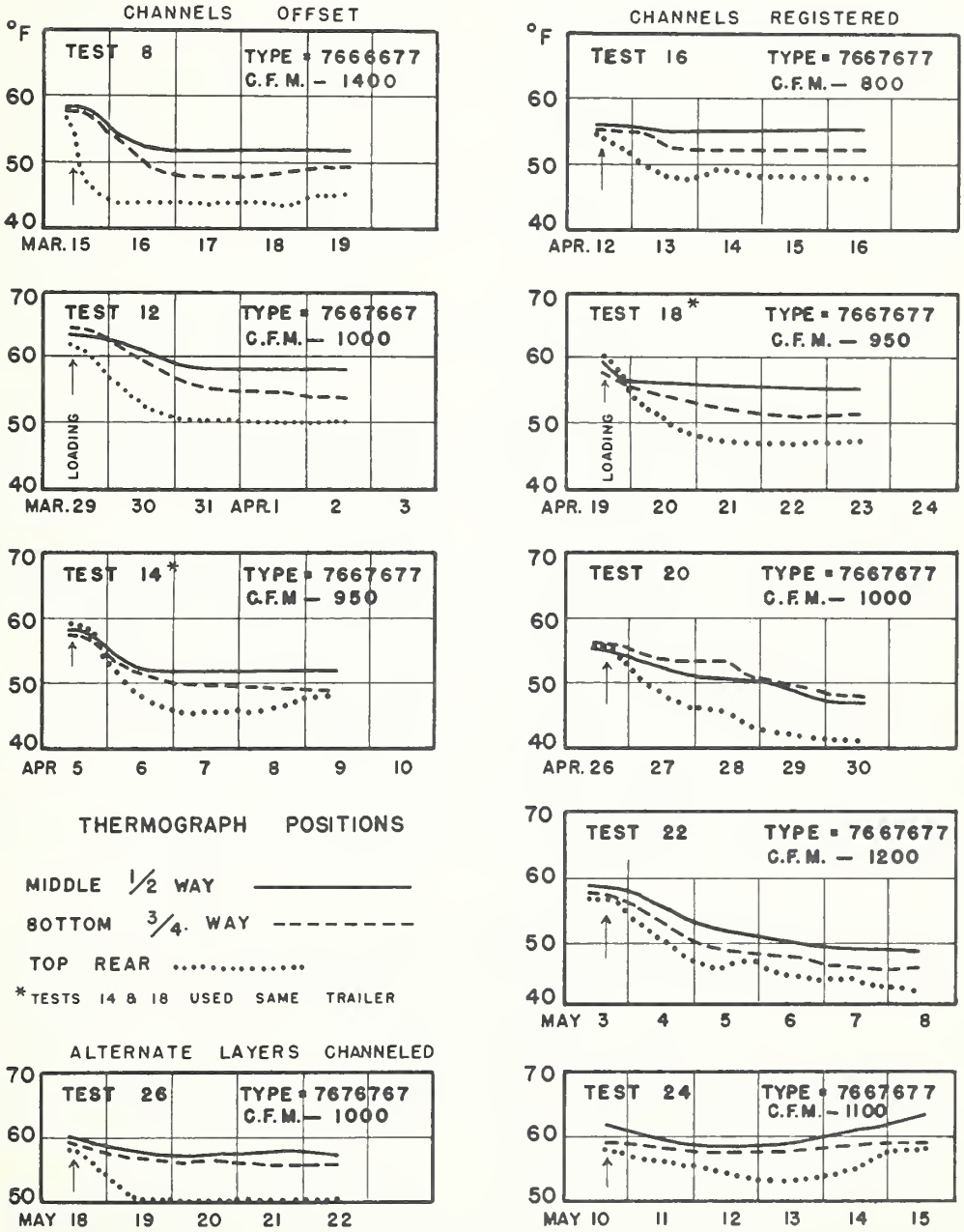
Temperatures of oranges.--All the thermostats in the eight tests with oranges in channel loads were set at 35° F., but the actual cutoff temperature of the units ranged from 28° to 49°. This unreliability of the thermostats accounted for some of the poor cooling in many of the tests. The average temperature reductions, as recorded by five thermographs 48 hours after loading, are given below:

Test	°F. reduction	Test	°F. reduction
11	9.8	19	5.0
13	13.4	21	13.5
15	10.8	23	19.2
17	17.2	25	22.0

LEMON TEMPERATURES IN MECHANICALLY REFRIGERATED TRUCK TRAILERS WITH VARIOUS TYPES OF CHANNEL LOADS

SOUTHERN CALIFORNIA TO CHICAGO

THERMOSTAT SETTING = 46°



U. S. DEPARTMENT OF AGRICULTURE NEG. AMS 168-62 (3) AGRICULTURAL MARKETING SERVICE

Figure 5

The middle halfway temperature in test 11 was very high (61.0° F.) at arrival (fig. 6). This was caused by a dislocation of the central baffle, permitting the cool air to short circuit back to the evaporator without passing through the channels in the load. Also, the air temperature did not reach 50° until about 12 hours before destination and cooling was therefore limited. With the baffle in place a temperature curve similar to that of test 21 could have been expected.

The average temperature in test 13 dropped about 13 degrees F. the first 48 hours after loading. The graphs show practically no cooling after 60 hours because of a rise in temperature of the delivery air from the unit (fig. 6). Observers at destination reported 40 wet cartons under the evaporator in this test. The moisture could have come from an excessive amount of ice having formed on the evaporator, which in turn would have retarded cooling by restricting the air supply. No drain stoppage was noted at destination.

Only 800 c.f.m. of air circulated through the load in test 15. The cutoff temperature of 43° F. was reached about 40 hours after loading. The temperature of the cooling air then gradually rose to about 55° at arrival; consequently most of the fruit in the load cooled slowly.

Test 19 with a thermostat setting of 35° had the highest cutoff temperature (49° F.) of any thermostat in this group of tests, and as a result the load cooled very little (fig. 6).

The slow reduction in temperature at the top rear positions in test 21 indicates an inefficiently operating refrigeration unit (fig. 6). The cause might have been valves out of adjustment or an airflow rate of less than the 1,000 c.f.m. measured at loading. An efficiency check of this refrigeration unit before loading would have been desirable. Observers at unloading reported that the load arrived in good order.

Tests 17, 23, and 25 had the greatest average temperature reductions in 48 hours after loading and are examples of good cooling. They indicate that satisfactory transit temperatures are possible even for a commodity such as warm oranges.

The actual cutoff temperature of the thermostat in test 17 was lower (28° F.) than the setting of 35° and was reached about 36 hours after loading. The temperature of the air from the unit then gradually increased to 42° by arrival time, and the load cooled little after the first 48 hours. Average fruit temperature for five thermographs was 69° at loading, and 48 hours after loading it was 52°, a reduction of 17 degrees. The load arrived at destination with an average temperature of 48° (table 2). Temperatures taken with fruit thermometers in 42 locations throughout the load ranged from 43° to 54°.

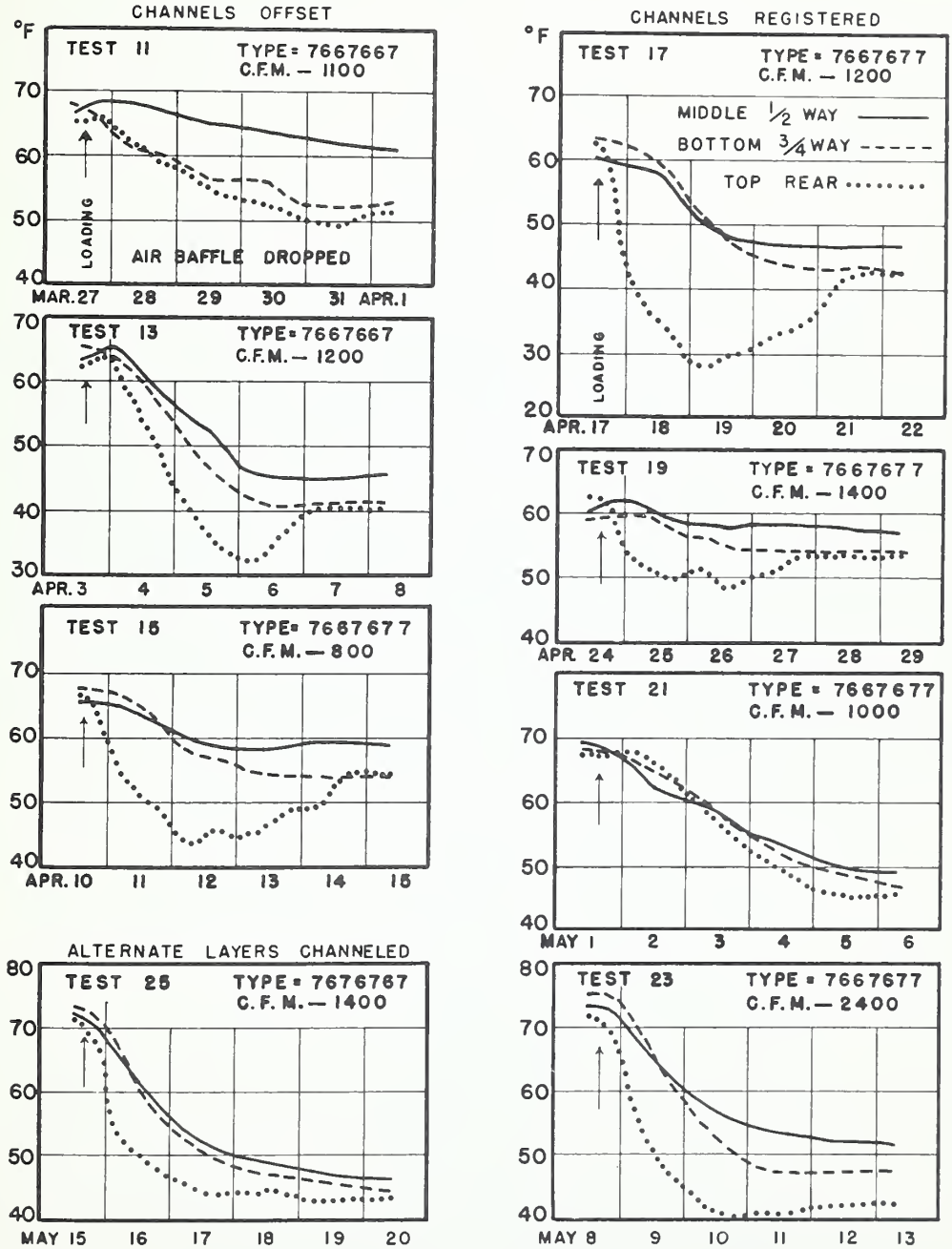
Test 23 showed an average reduction of 19 degrees F. in the first 48 hours after loading. The airflow of 2,400 c.f.m. at loading was the highest measured on any of the tests. The unit cut off at about 40° and maintained this temperature to destination. The widest temperature spread between cooling air and middle halfway position was 15 degrees about 36 hours after loading. The spread was about 10 degrees at destination. Inspection on arrival showed some cartons had shifted to the left in this load, and two cartons were damaged. The shift apparently closed some channels and caused the wide spread in temperature between cold air from the evaporator and the middle positions, but the cooling rate was good. Fruit temperatures taken with thermometers at 42 locations at unloading ranged from 45° to 56°.

Test 25 had a cutoff temperature of 42° F. for a thermostat setting of 35° and an airflow rate of 1,400 c.f.m. The average temperature was reduced 22 degrees 48 hours after loading. This load arrived in Chicago with an average temperature of 45.6° and a spread of 7 degrees (44° to 51°) between thermograph positions. The cooling accomplished in this test was excellent (fig. 6) and shows that all the equipment was functioning properly.

NAVEL ORANGE TEMPERATURES IN MECHANICALLY REFRIGERATED TRUCK TRAILERS WITH VARIOUS TYPES OF CHANNEL LOADS

SOUTHERN CALIFORNIA TO CHICAGO

THERMOSTAT SETTING = 35°



U. S. DEPARTMENT OF AGRICULTURE NEG. AMS 169-62 (3) AGRICULTURAL MARKETING SERVICE

Figure 6

DISCUSSION

Fruit condition upon arrival was good in all the tests. Temperature graphs for tests 23 and 25 show that loads with lengthwise air channels permit cooling warm oranges to an acceptable temperature during the first 48 to 72 hours of transit. The large carton area exposed to cold air passing through the channels permits rapid removal of heat, even from cartons near the center of the load. Other important factors contributing to good cooling are accurately calibrated thermostats, a high volume of airflow, and a refrigeration unit operating at maximum efficiency.

The trailers used in these tests were equipped with one temperature recorder with the sensing elements installed in the sidewall about halfway between front and rear and 30 inches from the floor. With refrigeration units in which the air circulating fan cycles on and off with the unit, this placement provides as good a record of load temperatures as can be obtained with widely varying load patterns. If positive air circulation through the load can be insured by using baffles to prevent the air from short circuiting back to the evaporator, and if the fan operates continuously regardless of unit cycling, then the sensing element will most nearly indicate load temperatures when it is placed in the return airstream to the evaporator.

Removable floor racks do not seem necessary with citrus fruit in channel loads during the cooler months of the year. Their use during exceptionally hot weather may help cool bottom layers, especially when the trailer floor channels are small. For the floor racks to be effective, provision should be made for the air to reach the evaporator from the spaces under the floor racks. Vertical channels in one or two of the forward stacks or a false bulkhead or return air duct installed in the nose, as shown in figures 1A and 2A, will allow this air to reach the evaporator.

The 6-inch space between the rear door and the load was ample. Spacers for maintaining channels were not necessary in trailers with pneumatic cushions. Equipment with spring or torsional suspension may require their use, however.

Another type of channel load has been developed by the Transportation and Facilities Research Division, Agricultural Marketing Service, United States Department of Agriculture. Drawings of this pattern are available from that office. The pattern is described by Russell H. Hinds, Jr., in Agricultural Marketing for October 1960.

Growth Through Agricultural Progress